Achieving Supportability on Exploration Missions with In-Space Servicing

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One of the long-term exploration goals of NASA is manned missions to Mars and other deep space robotic exploration. These missions would include sending astronauts along with scientific equipment to the surface of Mars for extended stay and returning the crew, science data and surface samples, and equipment to Earth. In order to achieve this goal, multiple precursor missions are required that would launch the crew, crew habitats, return vehicles and destination systems into space. Some of these payloads would then rendezvous in space for the trip to Mars, while others would be sent directly to the Martian surface. To support such an ambitious mission architecture, NASA must reduce cost, simplify logistics, re-use and/or repurpose flight hardware, and minimize resources needed for refurbishment. In-space servicing is a means to achieving these goals. By designing a mission architecture that relies on the concept of in-space servicing (robotic and manned), maximum supportability can be achieved.

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The Satellite Servicing Capabilities Office (SSCO) at the NASA's Goddard Space Flight Center (GSFC) has been and continues to develop technologies that are advancing the Technology Readiness Level (TRL) of several key technologies required for future missions to utilize in-space servicing with both ground and ISS on-orbit demonstrations.

The ability to refuel various chemical propellants of future exploration vehicles in space would allow those vehicles to be re-used and/or re-purposed multiple times without returning them to Earth. SSCO has conducted multiple demonstrations to support this future capability. The Robotic Refueling Mission (RRM) was an ISS payload that demonstrated the capability for a ground controlled in-space robotic system to access a typical satellite fill and drain valve and transfer fluid across the interface. This operation included cutting the wires and the removing the ancillary safety caps placed on these valves before launch, connecting a nozzle tool to the exposed valve, actuating the valve from the servicer, and transferring fluid through it. NASA was able to achieve these objectives with specially designed robotic tools that launched as part of the RRM payload and used by the dexterous robot on ISS - Dextre. A fluid transfer system on-board also controlled by operators on the ground simulated a robotic servicer fluid system parameters that would be required to refuel a client spacecraft. In a subsequent equally ambitions technology advancement campaign, a ground demonstration at Kennedy Space Center (KSC) transferred a hypergolic liquid oxidizer through an advanced Propellant Transfer Subsystem (PTS) into a satellite mockup at client pressures and flowrates. This operation included a seal-less Transfer Hose Assembly, specially designed for use on a robotic servicer, which connected the PTS to an Oxidizer Nozzle Tool / Quick Disconnect at the end of a robotic arm that was robotically mated to the client fill-drain valve. The robot system utilized was remotely controlled by an operator at GSFC to simulate the effect of an operator on the ground controlling a system in space, including control delay times.

One of the key components of a NASA mission to Mars will be the use of Solar Electric Propulsion (SEP) for the long distance cruise phases, with the use of hypergolics (or other chemical propellant alternatives in work) for RPO maneuvers and other critical rapid thrust burns. These SEP systems would use xenon as a propellant. As a proof of concept demonstration, SSCO is currently planning xenon transfer on an external platform mounted to ISS. This demonstration would transfer high pressure supercritical xenon gas across a robotically mated valve, which is being custom designed to support cooperative robotic transfers on future spacecraft. This demonstration would also feature a new xenon transfer device extensible for larger volume applications such as the Asteroid Redirect Mission. Development for these technologies is already underway with the flight demonstration onboard ISS scheduled for 2017.

Fully autonomous rendezvous and proximity operations systems will be another enabling technology for a mission to Mars. All multi-launch mission architectures—crew vehicle, habitat module, transfer vehicle, surface lander—will require the mating of separate flight components together in Earth, Lunar, or Martian orbits. Since NASA can control both sides of the mating interface, these docking events can be simplified using the many cooperative interfaces—such as communication and ranging cross-links, cooperative navigation targets, and common berthing and docking standards—being currently utilized during rendezvous and docking operations with the ISS. Advances in autonomous operations will be needed to address the added challenge of a deep-

space rendezvous outside a real time communications link with Earth and between multiple un-crewed vehicles. Through its Raven relative navigation experiment and its robotic servicing mission designs, the SSCO is developing the necessary technologies to bridge the autonomous operations gap that exists today, with specific attention paid to how to verify the complex interplay between autonomous software, relative scene dynamics, and environmental effects.

Liquid cryogens also have multiple uses on long-term exploration missions. They can be used as propellants and in cooling or life support systems. One demonstration on the upcoming RRM3 payload will be to test a newly-designed cryogen coupler. This coupler would be the primary interface between a servicing vehicle and an exploration vehicle in need of replenishment. It could also enable cryogenic replenishment of a planetary habitat. The coupler demonstration on RRM3 will show that a mechanism can be robotically installed with minimal actuation that is capable of creating a sealed interface for the transfer of liquid cryogens. And while the RRM3 demonstration will be robotic only, one goal of the design is to allow simple crossover to a human actuated interface. In addition, other key technology demonstrations will be included.

The benefits of leveraging space servicing technologies to building a sustainable solar system exploration architecture are numerous. Hardware that can refueled or replenished without returning to Earth can be cheaper, simpler, and last longer. A robotic servicer designed to provide the needed refurbishment the exploration vehicles require could remain in space at the designated rendezvous points and be accessed multiple times. Major future mission elements could be placed into initial orbits partially fueled, enabling more Payload launch weight dedicated to science and personnel, and topped off by pre-positioned servicer or depot, before departing for its designated long range mission. Vehicles that can be re-purposed through refueling could have multiple mission functions – a spacecraft designed for studying asteroids could be refueled and sent on a mission to Mars or used for planetary defense purposes. With in-orbit servicing as a tenant of future architectures, it is logical to design common interfaces, which would be duplicated across the fleet – reducing cost via reduced non-recurring engineering. Most servicing spacecraft would be unmanned to avoid the logistics involved in manned missions, but the applications developed could be applied to manned use as well, allowing human servicing of vehicles or habitats on planetary surfaces where resources available on Earth for complicated repairs would be unavailable or in short supply. Building servicing into an advanced mission architecture like manned missions to Mars or the Asteroid Redirect Mission minimizes logistics and operations, minimizes maintenance complexity, and allows the re-use and re-purposing of flight hardware. This supportability minimizes the cost and increases the efficiency of these NASA programs. Creating this servicing capability / infrastructure will also lead NASA to new missions and places not presently deemed possible once the complement for the production of propellant from in space resources / regolith is also successfully demonstrated by others.